ADVANCED METALLIC SEAL FOR HIGH TEMPERATURE APPLICATIONS

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The U-Plex® seal is a static seal. It consists of two plies of material nested together during the forming process, that act independently when the seal is compressed, like a multi-leaf spring, yet act as one in containing pressure. Please note that most of the testing that has been done, and most of actual applications in service are small (less than 8 inches) diameter seals. However, we are in fact testing and refining the manufacturing process for the larger diameter seals and the benefits that apply to the small seals are applicable to U-Plex® Seals of any size.

What the U-Plex® seal does is improve the integrity and robustness of rigid ducting joints. What you get is increased elastic deflection. To illustrate this, I have a scale side-by-side comparison of the U-Plex® seal and the now conventional E-Seal®. The U-Plex® Seal is a static, reusable seal, and it is designed to operate in the elastic range of material. The object is to hold the seal as high as possible in the free state, yet not permanently deform the seal when it is compressed it in the cavity. A scale comparison of a standard section E-Seal® and a standard section U-Plex® Seal and the corresponding industry standard cavity dimension shows that when you compress the E-Seal®, you compress it .013 inches on each side. When the U-Plex® Seal is compressed, their is an additional amount of compression (.007 inches) per side. This extra .014 inches of compression is additional stored springback capability for the seal, so that if the cavity deforms during operation, the U-Plex® Seal has the ability to conform to the new cavity dimension and maintain contact with the sealing face. This is partially due to the multi-ply technology, but is also due to the geometry of the cross-section. A stress plot of a standard E-Seal® in its maximum (.027 inches) compression position shows that at the maximum stress level, which in this case actually slightly does exceed the yield stress of the material, has saturated about 50% of the cross-section. A similar stress plot of a U-Plex® Seal (maximum compression of .040 inches) shows that the plies do, in fact, act independently in distributing the stress, and that only about 10% of the section is saturated with a stress level that approaches the yield stress of the material. The actual amount of compression is an additional 50% over what you would get with the standard E-Seal®. The benefit of all this is that the U-Plex® Seal is much more compliant, and stores additional springback capability, so if the flanges or the sealing face is warped, or out-of-flat for any reason, the U-Plex® can conform and maintain a good quality seal. For the rigid joint applications, the U-Plex® Seal is capable of handling two-and-a-half to five times the amount of flange warpage or out of flatness, that a normal E-Seal® can handle. This translates into less rework of your ducting joints. The seal is also very locally compliant. The sealing face flatness can deviate up to .018 inches per inch of circumference. This far exceeds the capability of a standard E-Seal®. What is the benefit of this feature ? The same as for deflection capability. If your sealing face is out of flat or

distorts due to welding, the U-Plex® Seal has exceptional ability to conform and provide a good quality seal.

Both E-Seals® and U-Plex® Seals are pressure-energized seals. The graph of leakage in SCFM per inch of duct diameter as a function of seal face separation shows how the U-Plex® Seal has improved pressure energization characteristics. This data shows that a nominal free height E-Seal® (which is .108 inches tall), will seal well below the .01 SCFM per inch of tube diameter industry standard, until the distance between the sealing two faces exceed the unrestrained free height of the seal. In contrast, a nominal free height U-Plex® Seal (which is .121 inches tall), is capable of controlling leakage even when the distance between the two sealing faces exceeds the unrestrained free height of the seal. This is possible due to the increased flexibility of the multi-ply U-Plex® Seal design and its exceptional ability to energize open and conform to an irregular surface under pressure. Because these two seals are designed to operate in the same cavity, you actually gain an additional .020 inches of possible cavity width variation before leakage becomes a problem.

Extensive testing has been done on this seal. The most rigorous test that has done is an accelerated life test (SAE AS1895 Endurance Test) where the pressure is cycled and a large bending moment is cyclically applied to the pneumatic joint. This test was run at 1200°F for 200,000 cycles, and the leakage rate was measured and plotted every 20,000 cycles. The actual leakage at all of the different 20,000 cycle intervals never exceeded 10% of the .01 SCFM / inch of diameter allowable leakage. After 200,000 cycles, the measured leakage was 4% of the allowable leakage

The standard U-Plex® Seal cross section is an internally pressurized two-ply, single convolution design. However, the number of material plies and the material thickness may be varied, convolutions may be added, and an externally pressurized version is also possible. There are a lot of options for this design.

Finally, all of the benefits that exist in the pneumatic joint application are applicable for use in a turbine engine. The same physical principles are at work, only on a larger scale. The increased elastic deflection feature is useful for segmented cavity surfaces. If the segmented cavity isn't flat, if it has bumps in it, the U-Plex® Seal is better able to conform and provide a tight seal. The design minimizes the likelihood of stress relaxation at high temperature. And the testing has shown a greater resistance to high cycle fatigue.

QUESTIONS

Q. What's the material?

A. Well, we can make that a variety of materials. The standard seal is made out of Inconel 718.

Q. Is the manufacturing of that seal mature now?

A. The small diameter seal is a very mature process, yes.

Q. Small being?

A. Up to about 7 or 8 inches in diameter.

Q. Have you ever made an 18 inch or larger?

A, We have made up to about three feet. For the three foot diameter seals, the process however, is being developed and testing for the large seals in process.

Q. Can you make a really large diameter seal?

A. It's never been done but the process is being developed.

Q. Do you expect wear vibrations between the two parts of the seal.

A. Well, part of the ASC 95 test is in fact a very rigorous vibration test that we have in fact done successfully with no visible or performance changes that we know.

METALLIC

U-PLEX SEALS

INTRODUCTION

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- *Introduction to the U-Plex Seal*
- *Rigid Joint Features and Benefits*
- *Test Data*
- *Stress Plots*
- *Turbine Engine Benefits*

U-PLEX CROSS SECTION

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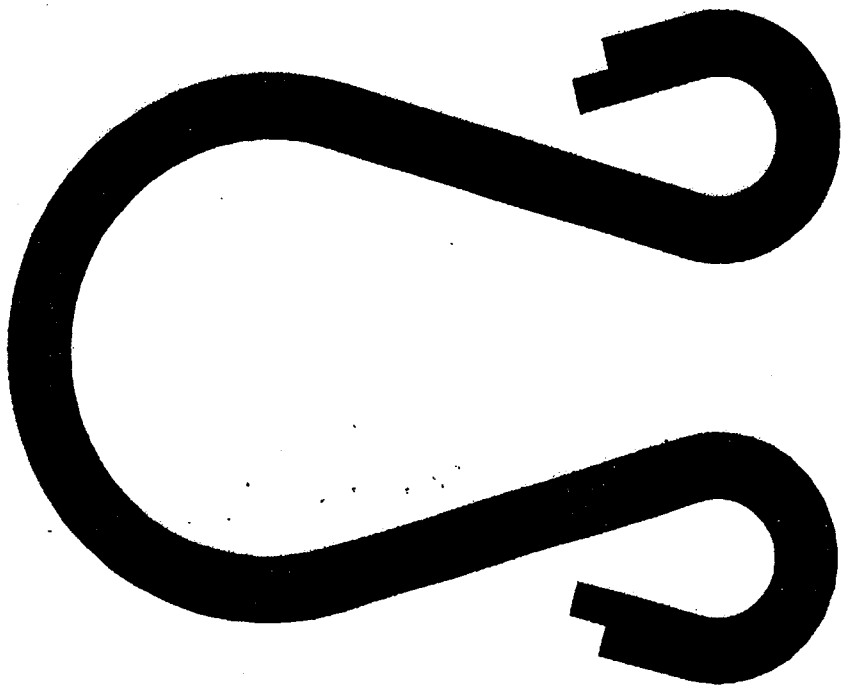

RIGID JOINTS

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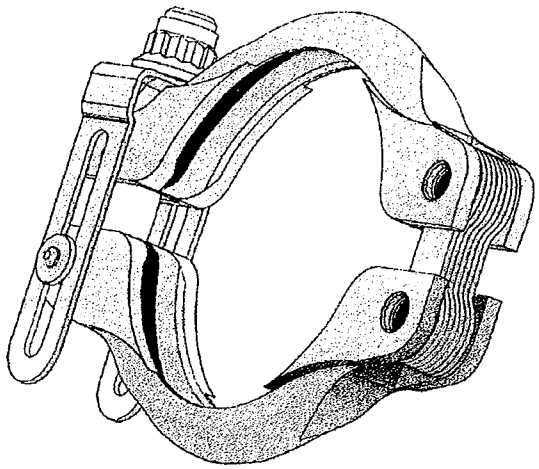
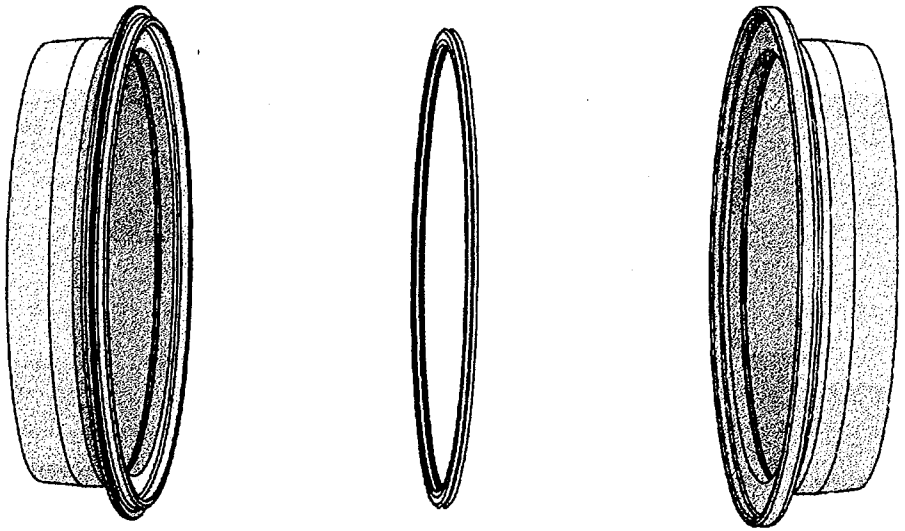
- Life-of-the-Aircraft
- Best for ducts needing frequent access.
- High reliability.
- Robust design for ease of maintenance.



Psi Coupling

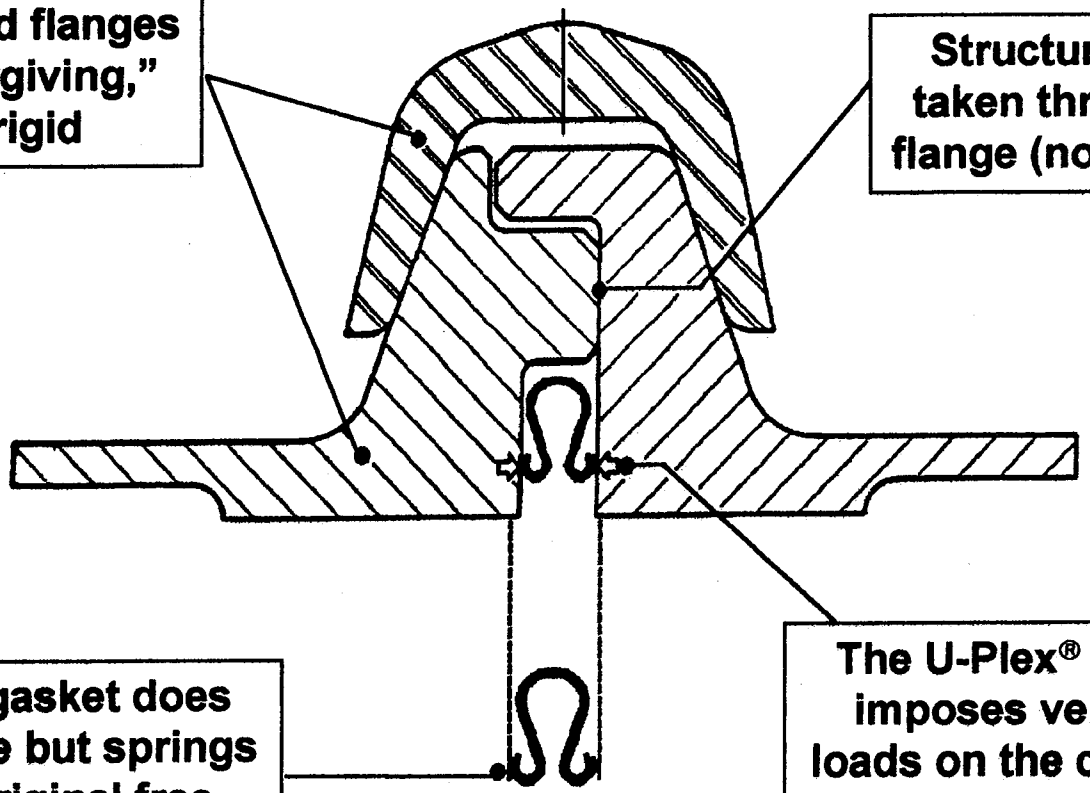


Male Flange U-Plex® Seal Female Flange

U-PLEX RIGID JOINT

Coupling and flanges are not "forgiving," i.e. are rigid

Structural loads taken through the flange (not the seal)



The U-Plex® gasket does not yield in use but springs back to its original free height, so it is re-usable.

The U-Plex® gasket imposes very low loads on the coupling (around 25 lbs/inch).

LEAKAGE CONTROL BETTER THAN .01 SCFM PER INCH OF DUCT DIAMETER AT OPERATING CONDITIONS

JOINT DEFLECTIONS

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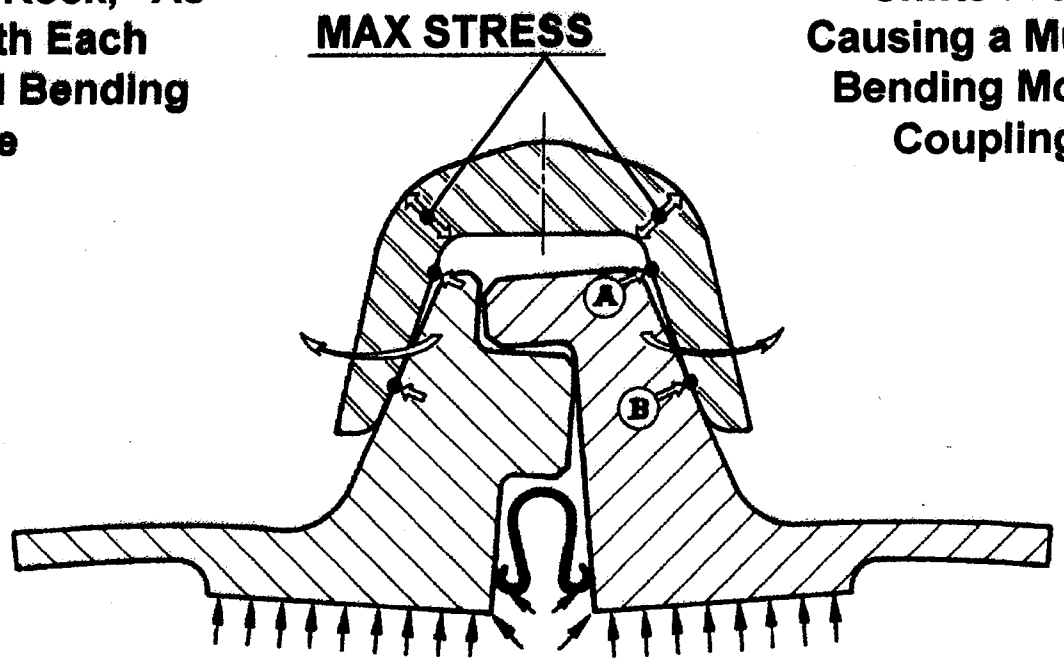
The Flanges "Rock," As Shown, With Each Pressure and Bending Cycle



The Load on the Coupling Shifts From Ⓐ to Ⓑ Causing a Much Increased Bending Moment on the Coupling Channel

THE SEAL "OPENS" AND "CLOSES" WITH EACH CYCLE

A Single Pressure Science Joint Was Qualified Through 1,100,000 Pressure Impulse Cycles Combined With 221,000 Bending Moment Cycles, Equivalent to 100,000 Flight Hours.

U-PLEX RIGID JOINT

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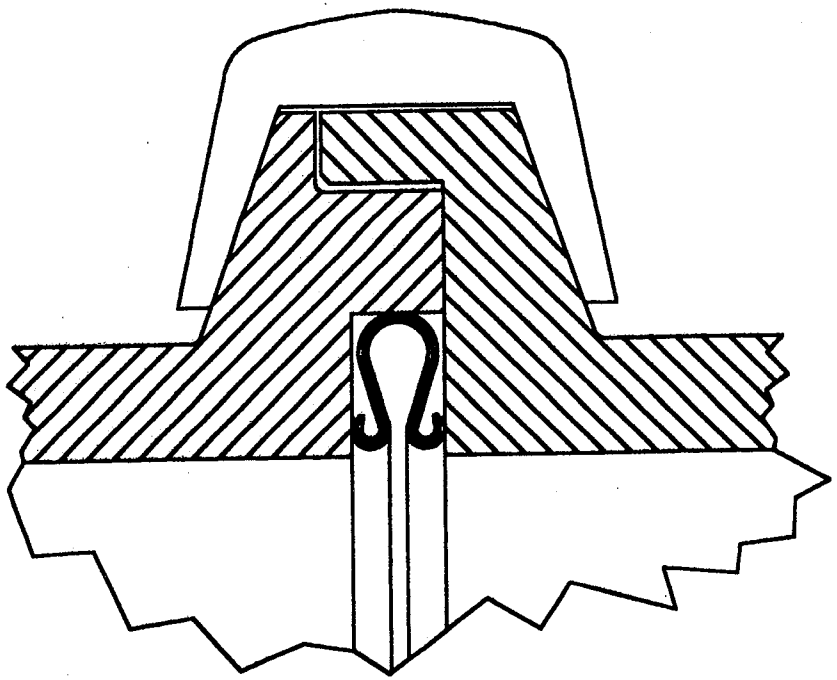
- *Improves the Integrity and Robustness of Rigid Ducting Joints.*



- *Used on Turbine Engine Bleed Systems, Ecs, Anti-Ice, Etc.*

INCREASED ELASTIC DEFLECTION

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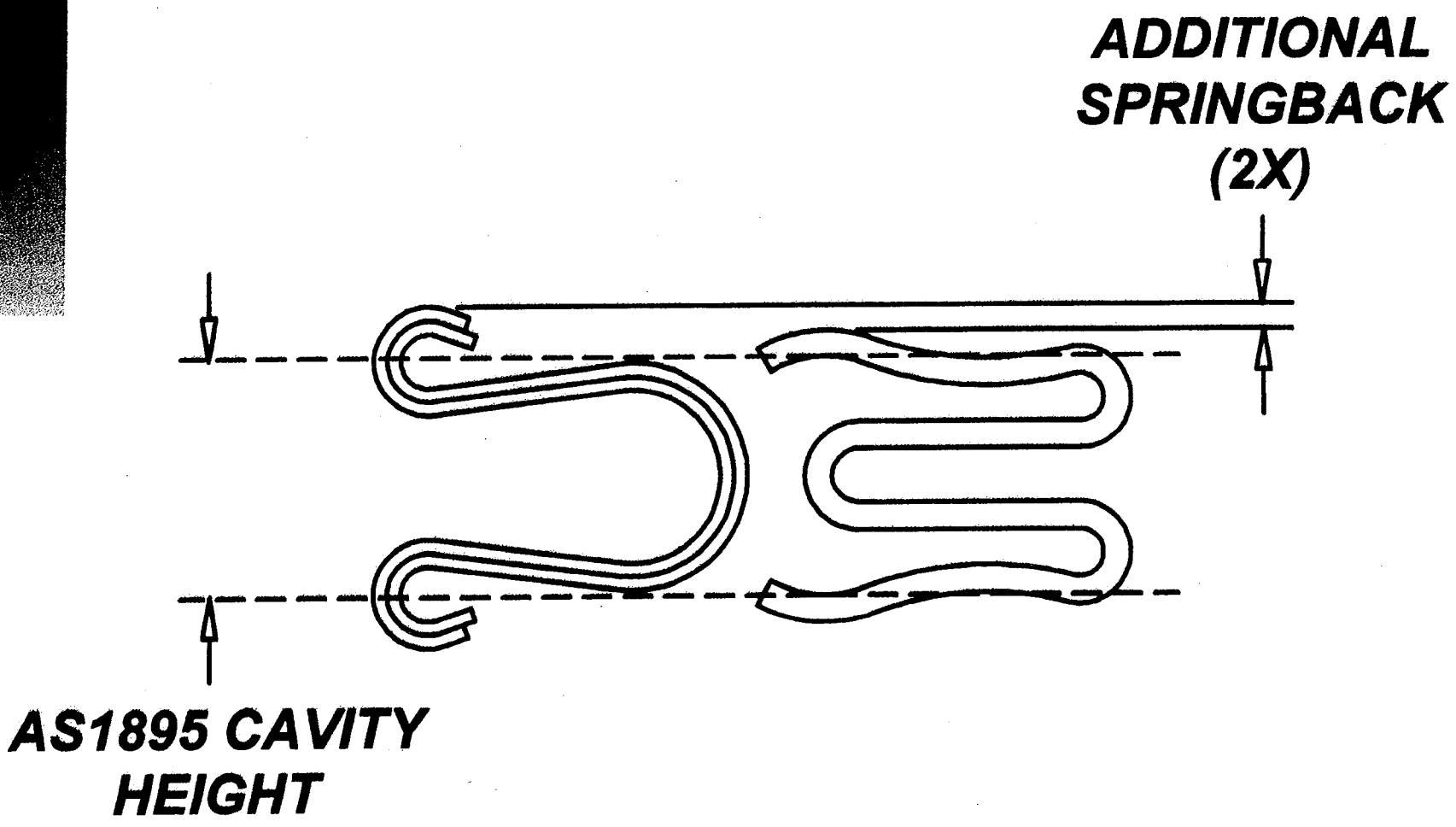

INCREASED ELASTIC DEFLECTION

■ BENEFITS

- **Will Seal Weld Distorted Flanges**
  (as much as 2.5 to 5 times the deformation accommodated by the standard E-seal)
- **Less Rework of Ducting Joints**
- **Relaxed Flange Flatness**
- **Requirements**
- **Reduced Manufacturing and Operating Cost for User**

FLANGE FLATNESS REQUIREMENTS

STANDARD E-SEAL

1.50 to 4.50 inch Duct OD ⇒ .005" TIR

5.00 to 7.00 inch Duct OD ⇒ .007" TIR

7.50 inch Duct OD ⇒ .008" TIR

U-PLEX SEAL

1.50 to 3.50 inch Duct OD Low Profile ⇒ .013" (*) Standard Profile ⇒ .015" (*)

3.50 to 7.50 inch Duct OD Low Profile ⇒ .026" (*) Standard Profile ⇒ .020"

U-PLEX FEATURES

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- **FEATURE**
  - Conforms to Local Deformation
    - 1.50 to 3.50 DUCT OD ⇒ .O11" per linear circumference
    - >3.50 to 7.50 DUCT OD ⇒ .018" per linear circumference
- **BENEFIT**
  - Reduces Rework/Replacement Cost of Improperly Welded Flanges

MAXIMUM STRESS

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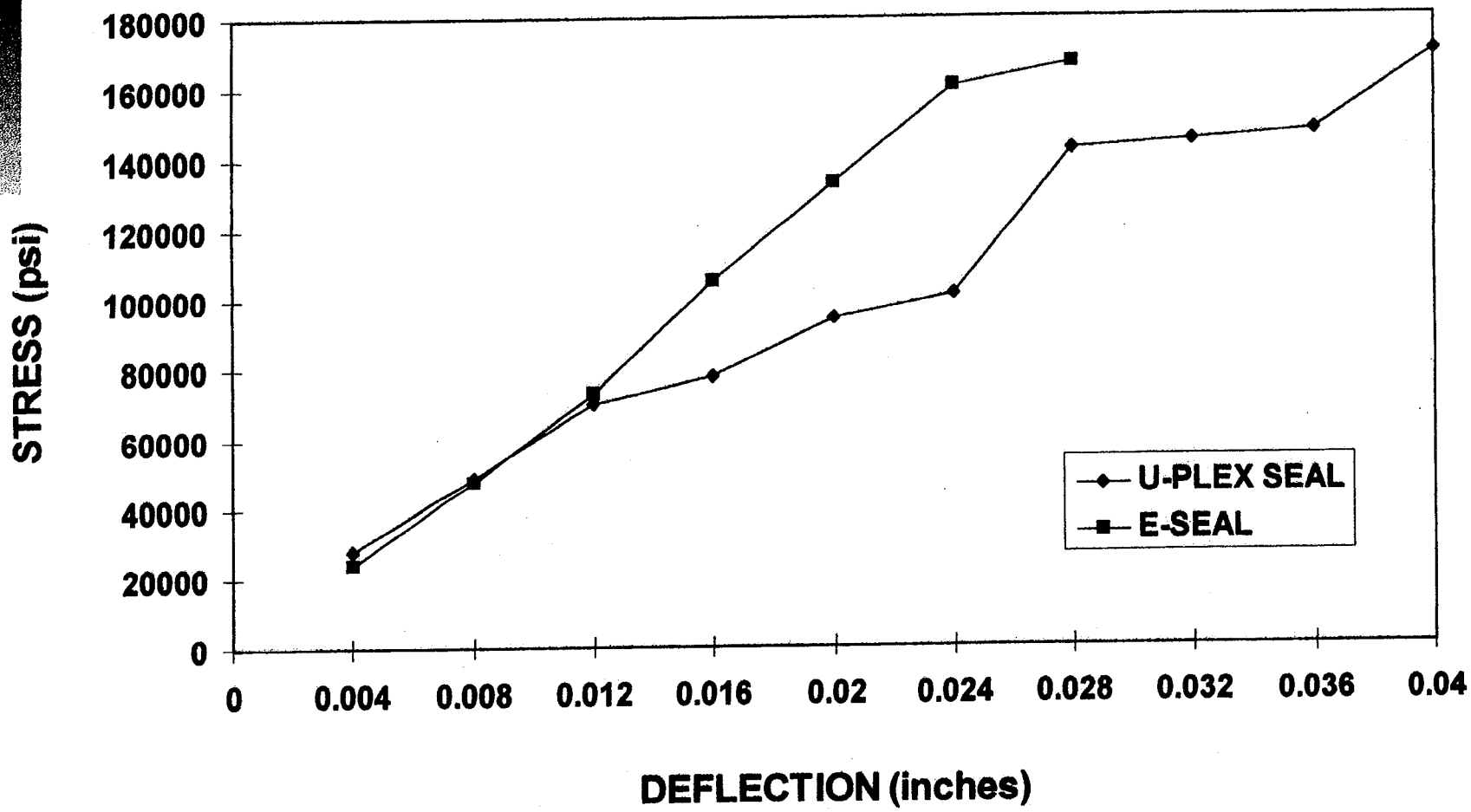
@ 10% SECTION SATURATION vs. DEFLECTION



FLAT CAVITY LEAKAGE

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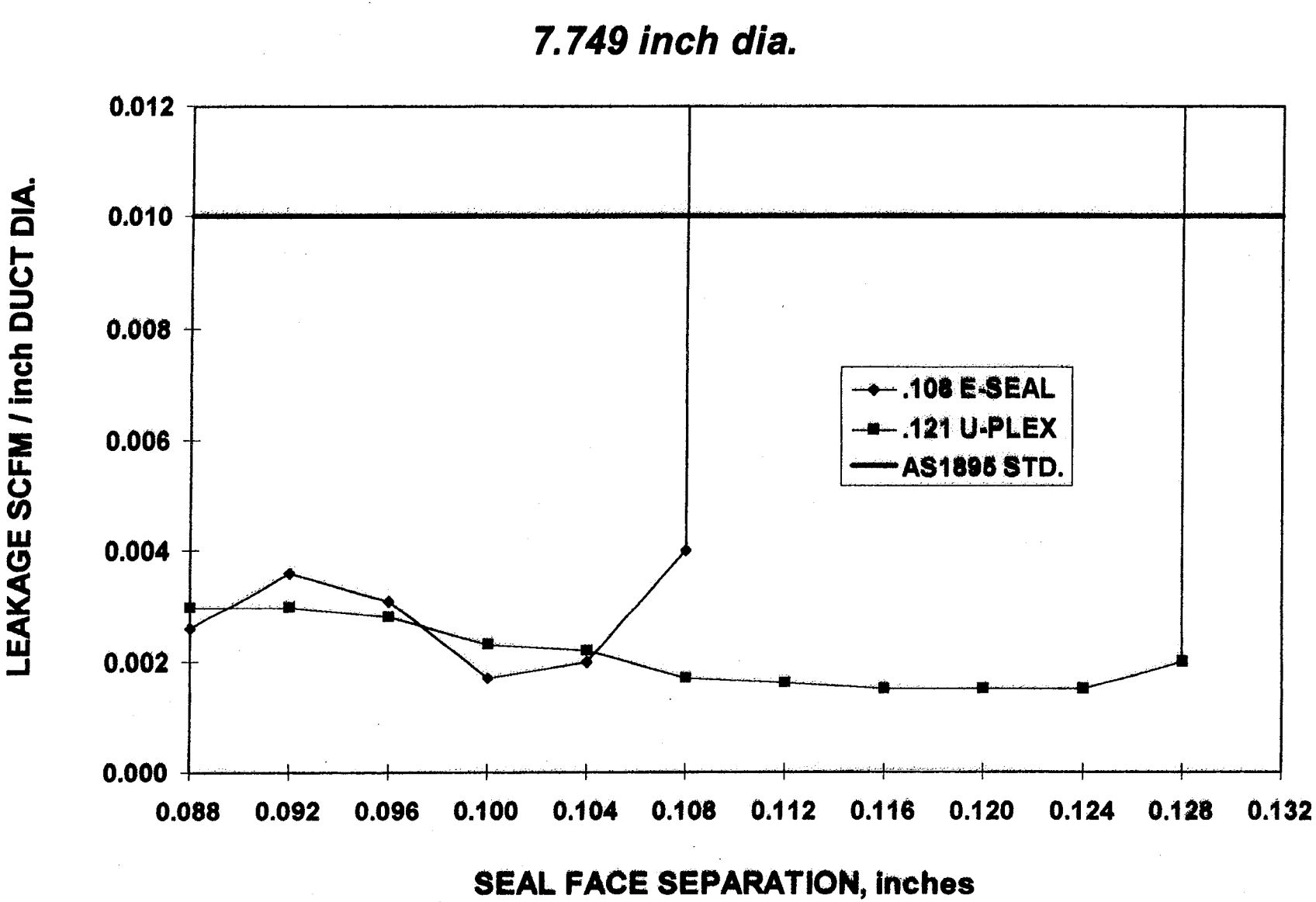

U-PLEX FEATURES

- **FEATURE**
  - Lower Force to Compress
    - E-SEAL ≈ 60 lbs./circumferential inch
    - U-PLEX ≈ 20 lbs./circumferential inch

- **BENEFIT**
  - Leakage Rate Comparable to That of an E-Seal, Less Wear of the Flange Sealing Faces.

SAE AS1895 ENDURANCE TEST

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- 0 psi - 250 psi PRESSURE CYCLE
- 0 in/lb - 6344 in/lb FLEXTURE CYCLE
- 1200°F TEST TEMPERATURE
- 200,000 CYCLE TEST
- LEAKAGE TEST EVERY 20,000 CYCLES

AS1895 ENDURANCE TEST

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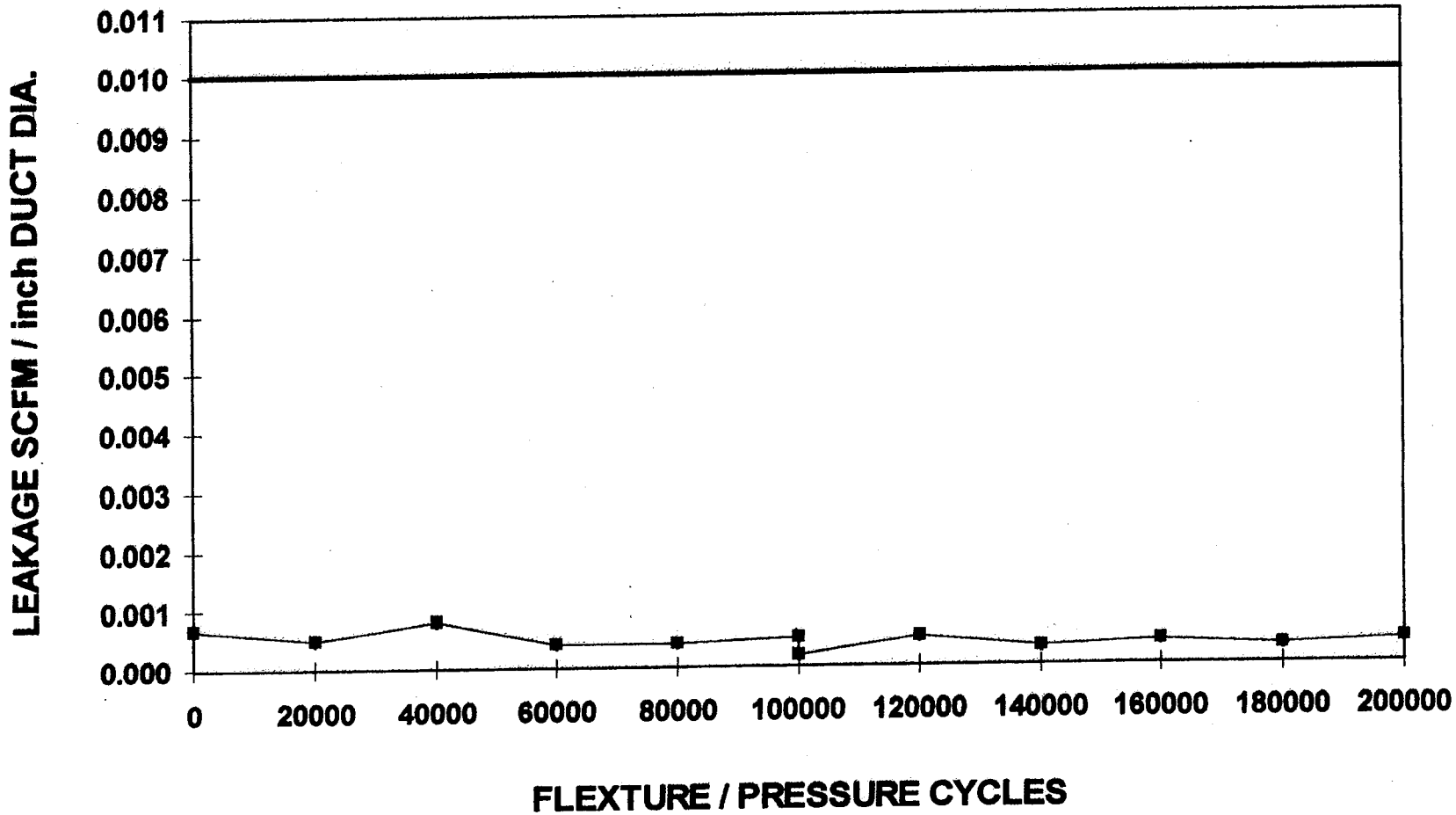
7.5 inch STD.PROFILE DUCT



AS1985 SAFETY LATCH TEST

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- Simulated Catastrophic Bolt Failure
- Test Must Be Run 10 Times
- Allowable Leakage
  = 6 SCFM Per INCH DUCT DIA
- Maximum Actual Leakage
  = 5.08 SCFM Per INCH DUCT DIA

CUSTOM ENGINEERED SEALING RING SECTIONS

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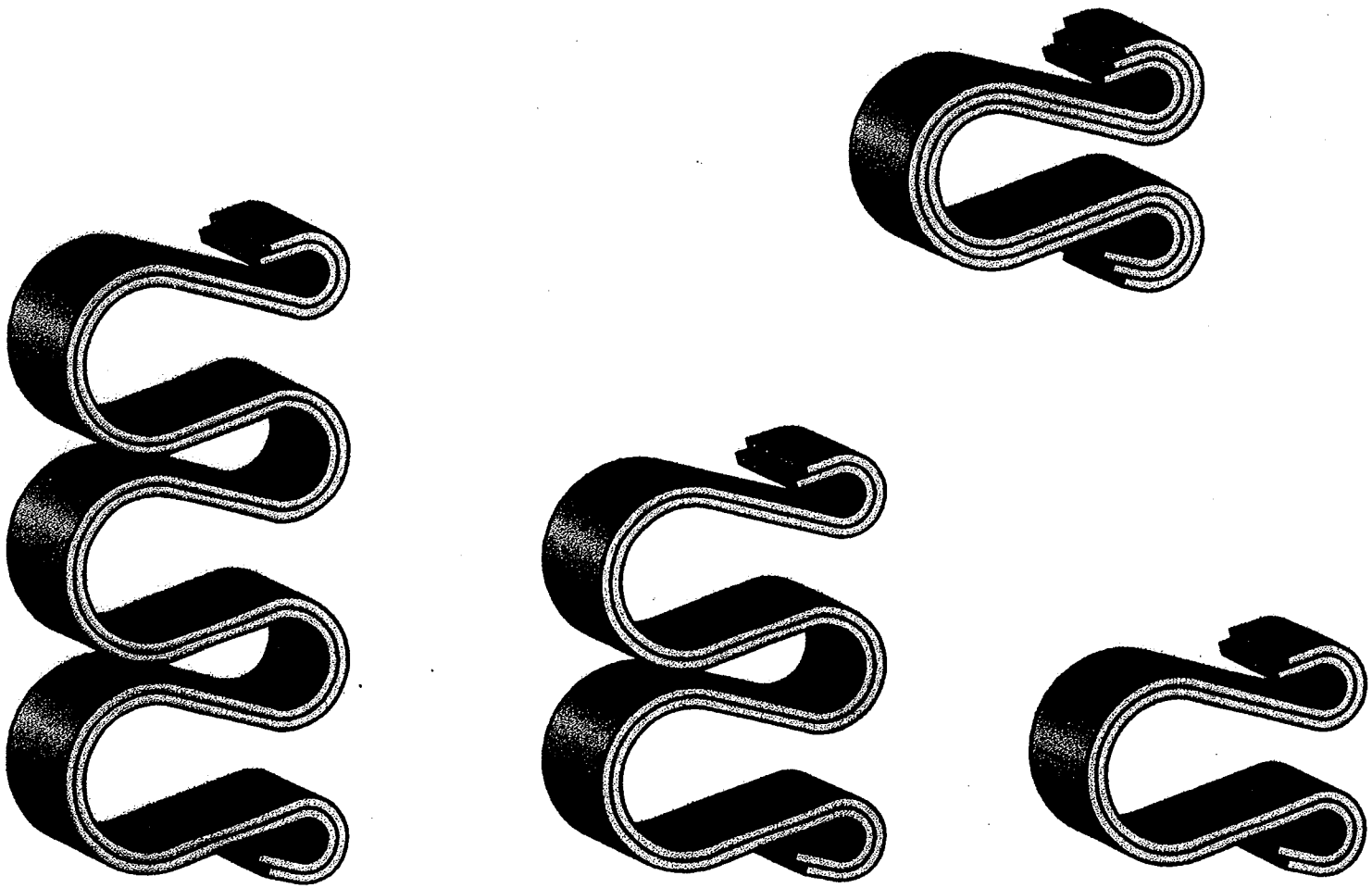

BENEFITS APPLICABLE TO A TURBINE ENGINE

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- Increased Elastic Deflection / Conformance to Local Deformation
- Improved Pressure Energization
- Lower Force to Compress / Less Wear
- Minimized Stress Relaxation
- Greater Resistance to High Cycle Fatigue